Carbon Performance assessment of automobile manufacturers: methodology note

November 2023

Simon Dietz, Hayli Chiu, Nikolaus Hastreiter, Ali Amin and Valentin Jahn

Transition Pathway Initiative

LSE Grantham Research Institute on Climate Change and the Environment

About the LSE Transition Pathway Initiative Centre

The Transition Pathway Initiative Centre (TPI Centre) is an independent, authoritative source of research and data on the progress of corporate and sovereign entities in transitioning to a low-carbon economy.

The TPI Centre is part of the Grantham Research Institute on Climate Change and the Environment, which is based at the London School of Economics and Political Science (LSE). It is the academic partner of the Transition Pathway Initiative (TPI), a global initiative led by asset owners and supported by asset managers. As of October 2023, 143 investors globally, representing around US$60 trillion combined Assets Under Management and Advice, have pledged support for TPI. Using companies' publicly disclosed data, the TPI Centre:

- Assesses the quality of companies' governance and management of their carbon emissions and of risks and opportunities related to the low-carbon transition, in line with the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD).
- Assesses whether companies' current and planned future emissions are aligned with international climate targets and national climate pledges, including those made as part of the Paris Agreement.
- Provides the data for the Climate Action 100+ Net Zero Company Benchmark.
- Publishes its methods and results online and fully open access at www.transitionpathwayinitiative.org and on GitHub.

For more information visit www.transitionpathwayinitiative.org/

About the authors

Simon Dietz is the Research Director at the TPI Centre and a Professor of Environmental Policy in the Department of Geography and Environment at the London School of Economics and Political Science.

Hayli Chiu is a Research Analyst within the Carbon Performance team at the TPI Centre.

Nikolaus Hastreiter is a Researcher at the TPI Centre and a PhD student in the Department of Geography and Environment at the London School of Economics and Political Science.

Ali Amin is a Research Project Manager at the TPI Centre.

Valentin Jahn is a Principal Research Project Manager at the TPI Centre.

Acknowledgements

The authors thank Tess Sokol-Sachs for her contribution to the previous version of this report.

The views in this report are those of the authors and do not necessarily represent those of the host institutions or funders. The authors declare no conflict of interest in preparing this report. For the full disclaimer about the data and information published in this report, see page 21.

This paper was first published in October 2023 by the TPI Centre.

Suggested citation: Dietz S, Chiu H, Hastreiter N, Amin A and Jahn V (2023) *Carbon Performance assessment of automobile manufacturers: note on methodology*. London: Transition Pathway Initiative Centre, London School of Economics and Political Science.

Contents

List of abbreviations and glossary

BEV	Battery electric vehicle
CAFE	Corporate Average Fuel Economy standards [regulations in the US, first enacted in 1975, to improve the average fuel economy of cars and light trucks produced for sale in the US]
EV	Electric vehicle
FCEV	Fuel cell electric vehicle
ICCT	International Council on Clean Transportation
ICE	Internal combustion engine [vehicle]
IEA	International Energy Agency
JC08	Test cycle introduced by the Japanese 2005 emission regulation to determine fuel economy of automobiles for sale in Japan
Lge	Litres in gasoline equivalent
MoMo	Mobility Model [of the International Energy Agency]
NAFTA	North American Free Trade Agreement
NEDC	New European Driving Cycle [a driving cycle (collection of data points that represent the speed of a vehicle over time), last updated in 1997, designed to assess the emission levels of car engines and fuel economy in passenger cars]
NZE	Net Zero by 2050 scenario [of the International Energy Agency]
PHEV	Plug-in hybrid electric vehicle
SDA	Sectoral Decarbonisation Approach
STEPS	Stated Policies Scenario [of the International Energy Agency]
WLTP	Worldwide Harmonised Light Vehicle Test Procedure [test designed by the EU in 2017 to better assess the emission levels of car engines, updating the NEDC. It is believed that fuel economy values estimated through the WLTP cycle better reflects real-world emissions compared with the NEDC]

1. The TPI Centre's Carbon Performance assessment: the Sectoral Decarbonisation Approach (SDA)

The TPI Centre's Carbon Performance assessments have to date been predominantly based on the Sectoral Decarbonisation Approach (SDA).[1] The SDA translates greenhouse gas emission reduction targets made at the international level (e.g. under the 2015 UN Paris Agreement) into benchmarks against which the performance of individual companies can be compared.

The SDA recognises that different sectors of the economy (e.g. oil and gas production, electricity generation and automobile manufacturing) face different challenges arising from the low-carbon transition, including where emissions are concentrated in the value chain and how costly they are to reduce. Other approaches to translating international emissions targets into company benchmarks have applied the same decarbonisation pathway to all sectors, regardless of these differences. [1] Such approaches may result in suboptimal insights, as not all sectors have the same emissions profiles or face the same challenges: some sectors may be capable of faster decarbonisation, while others require more time and resources.

Therefore, the SDA takes a sector-by-sector approach, comparing companies within the same sector against each other and against sector-specific benchmarks, which establishes the performance of an average company aligned with international emissions targets.

The SDA can be applied by taking the following steps:

- A global carbon budget is established, which is consistent with international emissions targets, for example keeping global warming below 2°C. To do this rigorously, some input from a climate model is required.
- The global carbon budget is allocated across time and to different regions and industrial sectors. This typically requires an Integrated Assessment Model (IAM), and these models usually allocate emissions reductions by region and by sector according to where it is cheapest to reduce emissions and when. Cost-effectiveness is, however, subject to some constraints, such as political and societal preferences, and the availability of capital. This step is therefore driven primarily by economic and engineering considerations, but with some awareness of political and social factors.
- In order to compare companies of different sizes, sectoral emissions are normalised by a relevant measure of sectoral activity (e.g. physical production or economic activity). This results in a benchmark path for emissions intensity in each sector:

$$\text{Emissions intensity} = \frac{\text{Emissions}}{\text{Activity}}$$

[1] The Sectoral Decarbonisation Approach (SDA) was created by CDP, World Resources Institute (WRI) and the World Wide Fund for Nature (WWF) in 2015. See Science-Based Targets Initiative [SBTi]: https://sciencebasedtargets.org/resources/files/Sectoral-Decarbonization-Approach-Report.pdf.

- Assumptions about sectoral activity need to be consistent with the emissions modelled and therefore should be taken from the same economy–energy modelling where possible.
- Companies' recent and current emissions intensity is calculated, and their future emissions intensity is based on emissions targets they have set (this assumes companies meet their targets).[2] Together, these establish emissions intensity pathways for companies.
- Companies' emissions intensity pathways are compared with each other and with the relevant sectoral benchmark pathway.

[2] Alternatively, companies' future emissions intensity could be calculated based on other data companies provide on their business strategy and capital expenditure plans.

2. Applying the SDA to the automobile manufacturing sector

2.1. Deriving the benchmark pathways

The TPI Centre evaluates companies against benchmark pathways, which translate the emission reductions required by the Paris Agreement goals into a measurable trajectory at the sectoral level. For each sector benchmark path, the key inputs are:

- A timeline for economy-wide carbon emissions that is consistent with meeting a particular climate target (e.g. limiting global warming to 1.5°C) by keeping cumulative carbon emissions within the associated carbon budget
- A breakdown of this economy-wide emissions pathway into emissions from key sectors (the numerator of sectoral emissions intensity), including the sector in focus
- Consistent estimates of the timeline of physical production from, or economic activity in, the sector in focus (the denominator of sectoral emissions intensity).

The TPI Centre uses three scenarios to calculate the sectoral benchmark pathways for the auto manufacturing sector, based on modelling by the International Energy Agency (IEA):

1. A National Pledges scenario, which is consistent with the global emissions reductions pledged by countries as of mid-2022.[3] This scenario is derived from the IEA's Stated Policies Scenario (STEPS), as presented in the World Energy Outlook 2022 report. [2] According to the IEA, while this aggregate represents a departure from business-as-usual, it is currently insufficient to put the world on a path to limit warming to 2°C or below. This scenario is expected to lead to a global temperature increase of 2.5°C by 2100 with a probability of 50%.
2. A Below 2 Degrees scenario, which is consistent with the overall aim of the Paris Agreement to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels – albeit at the lower end of the range of ambition. This scenario is derived from the IEA's Announced Pledges Scenario (APS). It gives a probability of 50% of holding the global temperature increase to 1.7°C. [2]
3. A 1.5 Degrees scenario, which is consistent with the overall aim of the Paris Agreement at the high end of the range of ambition. This is derived from the IEA's Net Zero by 2050 scenario (NZE), which requires virtually all new passenger vehicles sold to have zero tailpipe emissions by 2035. The scenario gives a probability of 50% to limiting the global temperature increase to 1.5°C. [4]

The IEA's economy–energy model simulates the supply of energy and the path of emissions in different sectors burning fossil fuels, or consuming energy generated by burning fossil fuels, accounting for assumptions about key inputs such as economic and population growth. In low-carbon scenarios, the IEA model minimises the cost of adhering to a carbon budget by always allocating emissions reductions to sectors where they can be made most cheaply, subject to some constraints as mentioned above. These scenarios are therefore cost-effective, within some limits of economic, political, social and technological feasibility.

[3] Commitments made close to or after the publication of IEA scenarios are not included.

For the auto manufacturing sector, the TPI Centre uses data from the IEA Mobility Model (MoMo), the IEA's specific module for the transport sector [3], combined with other IEA sources, including the World Energy Outlook 2022 [2], the Net Zero by 2050 (NZE 2050) report [4], the EV Outlook 2023 report [5] and Global Fuel Economy Initiative 2021 [6]. The MoMo projects fuel economy data for light-duty vehicles (LDVs) while other IEA reporting provides data on the projected share of electric vehicle (EV) sales under different low-carbon scenarios.

A central feature of auto manufacturing is that the majority of the sector's lifecycle emissions originate downstream, i.e. from fuel combustion that takes place when the vehicles that have been manufactured and sold are then driven.[4] It is therefore most appropriate to measure companies according to the performance of their vehicles. Companies' operational emissions from manufacturing (their Scope 1 and 2 emissions), while less important, are not completely unimportant, and the TPI Centre is exploring options for integrating these into future versions of the methodology. New vehicles are also the most appropriate focus as usage of existing stock is not normally within the scope of manufacturers' sustainability policies.

It has thus been suggested that a suitable measure of carbon performance in the auto manufacturing sector is the average emissions intensity of a company's fleet of new vehicles [7], and this is the approach being followed by the TPI Centre. By measuring the average emissions intensity of a new passenger car fleet, our benchmarks test if companies are on track to introduce zero tailpipe emissions vehicles, the key lever for decarbonising the sector fast enough to meet the Paris temperature goals. In the 1.5 Degrees scenario, virtually all new passenger vehicles sold – with some minor exceptions for hybrids – must have zero tailpipe emissions by 2035.

The scope of this analysis is limited to passenger cars due to the greater availability of manufacturer data on this subset of LDVs. To ensure the benchmarks are comparable with data on fleet emissions intensity commonly reported by manufacturers, the measure of fleet emissions intensity used by the TPI Centre is 'tank-to-wheel' CO_2 emissions per kilometre. This is based on the emissions produced via a vehicle's tailpipe over a specific distance travelled. By contrast, 'well-to-wheel' takes into account the entire lifecycle emissions, including those from energy production or fuel extraction, refining and distribution. Tank-to-wheel emissions based on real-world driving conditions are converted into equivalent emissions in test cycle conditions.

Following the industry's progress in adopting a test procedure that better reflects driving conditions in the real world, since our previous methodology update in January 2023 the TPI Centre has been using the Worldwide Harmonised Light Vehicle Test Procedure (WLTP) as the common basis for comparison across global manufacturers instead of the New European Driving Cycle (NEDC).

The TPI Centre relies on publicly disclosed fuel economy projections from the MoMo dataset, which cover all LDVs rather than exclusively passenger cars. [3] According to the European Automobile Manufacturers' Association (ACEA), passenger cars and passenger light trucks accounted for over 80% of total LDV sales in 2022. [8-9] Hence, we assume that the MoMo fuel economy projections for LDVs are the same as the fuel economy projections for passenger cars and passenger light trucks only.

To project the average emissions intensity of new vehicles for the three scenarios, the TPI Centre takes the following three steps:

1. Obtain scenario-specific fuel economy projections

For the National Pledges and 1.5 Degrees scenarios, the publicly available STEPS and NZE fuel economy values (WLTP) from MoMo are used. Data are given for the litres in gasoline equivalent per 100 kilometres(Lge/100km) of new LDVs for the years 2005–2050, in five-year increments. [3]

The IEA does not disclose fuel economy projections for the APS. To address this data gap, we estimate the fuel economy for the Below 2 Degrees scenario as the mid-point between STEPS and NZE.

2. Remove fuel economy for battery electric vehicles

The disclosed LDV fuel economy projections represent a weighted approach based on the proportions of battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and internal combustion engine vehicles (ICEs). For BEVs, a fuel economy of 1.87 Lge/100km is used as a proxy for savings in gasoline

[4] These emissions are categorised as 'use of sold products', a subset of Scope 3 emissions.

consumption due to the use of electricity. However, on a tank-to-wheel emissions intensity basis, BEVs produce zero tailpipe emissions. The fuel economy attributed to BEVs must therefore be removed from the projections.

To determine the fuel economy value for ICEs and PHEVs only, the fuel economy values for each type of vehicle (ICEs, PHEVs and BEVs) are calculated individually, then the fuel economy for ICEs and PHEVs are calculated by considering their respective market shares in total vehicle sales. The market sales data for each vehicle class was obtained from IEA's Net Zero by 2050 scenario [4], EV Outlook 2023 [5] and World Energy Outlook 2022. [2]

3. Convert fuel economy values into emissions intensities and re-weight

The fuel economy values in Lge/km are converted to gramme of CO_2 per kilometre (gCO_2/km) using factors published by the International Council on Clean Transportation (ICCT). [10] To account for the actual number of ICEs and PHEVs on the road, we multiply the converted value with the aggregated sales of ICEs and PHEVs.

Figure 1. Final benchmark emissions intensity pathways for automobile manufacturers

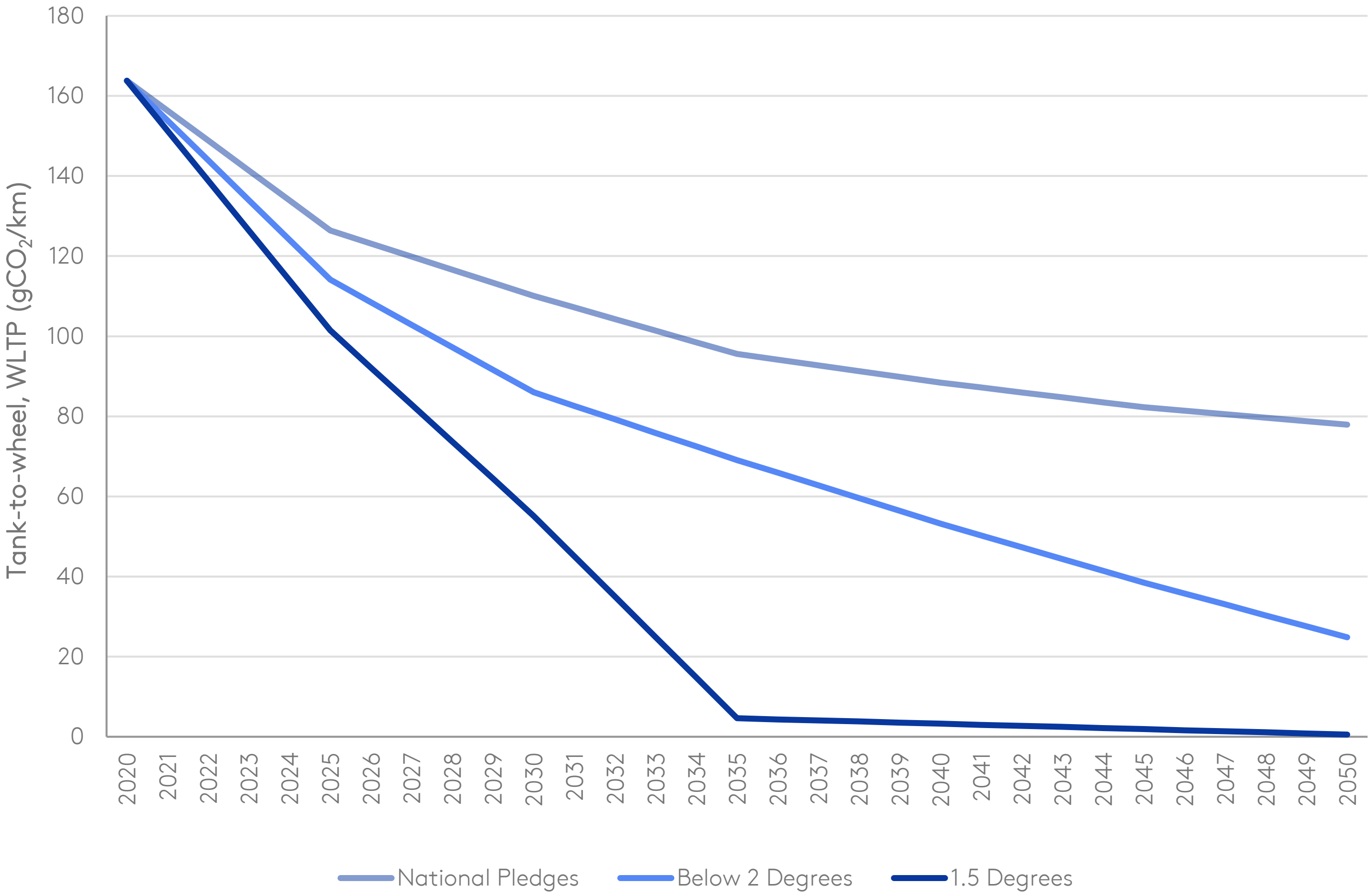


Table 1. Underlying tank-to-wheel, WLTP (gCO_2/km) emissions intensity data, 2020–2050

	2020	2025	2030	2035	2040	2045	2050
National Pledges	163.80	126.40	110.09	95.55	88.44	82.26	77.93
Below 2 Degrees	163.80	114.12	85.99	69.08	53.25	38.50	24.83
1.5 Degrees	163.80	101.46	55.16	4.62	3.26	1.90	0.54

Note: conversion factor from Lge/100km to gCO_2/km is 23.37, according to the ICCT.

2.2. Data sources and validation

In auto manufacturing, the primary sources of company data are companies' own disclosures (e.g. sustainability reports), responses to the annual CDP questionnaire, and publicly available information held by regulators. Sales data mostly come from company disclosures and emissions data mostly come from regulators.

Given that the TPI Centre's Carbon Performance assessment is both comparative and quantitative, it is essential to understand exactly what the data in company disclosures refer to. Company reporting varies not only in terms of what is reported, but also in terms of the level of detail and explanation provided. The following cases can be distinguished:

- Companies that provide data in a suitable form, and with enough detail for analysts to be confident that appropriate measures can be calculated or used.
- Companies that provide enough detail, but not in a form that is suitable for the assessment (e.g. they do not report the measure of company activity needed). Such companies cannot be included in the assessment.
- Companies that do not provide enough detail on the data disclosed and these data are also excluded from the assessment (e.g. the company reports an emissions intensity estimate but does not explain precisely what it refers to).
- Companies that do not disclose their carbon emissions or activity.

Once a company's preliminary performance assessment has been made based on the principles and procedures described above, it is subject to the following quality assurance:

- Internal review: the preliminary assessment is reviewed by analysts that were not originally involved in making it.
- Company review: once the initial findings review is complete, the TPI Centre writes to companies with their assessment requesting them to review it and confirm the accuracy of the disclosures used. The company review is done for all companies, including those who provide unsuitable or insufficiently detailed disclosures.
- Final assessment: company assessments are reviewed and, if appropriate, revised.

2.3. Responding to challenges from companies

Allowing companies the opportunity to review and, if necessary, to correct their assessments is an integral part of the TPI Centre's quality assurance process. Companies are permitted to contact us at any point to discuss their assessment. If a company seeks to challenge its result or representation, the process is as follows:

- TPI reviews the information provided by the company and requests additional information if required.

- If it is concluded that the company's challenge has merit, the assessment is updated and the company is informed.
- If it is concluded that there are insufficient grounds to change the assessment, the original assessment is published.
- If the company requests an explanation regarding its feedback after the publication of its assessment, an explanation is provided.
- If a company requests an update of its assessment based on publicly disclosed data after the research cut-off date communicated to the company, the new disclosure can be reflected on the company's profile on the TPI Centre website.
- If a company chooses to further contest the assessment and resorts to legal measures to do so, the company's assessment is withheld from the TPI Centre website and the company is identified as having challenged its assessment.

The results of the Carbon Performance assessment are posted on the TPI Centre website, within the TPI tool (https://www.transitionpathwayinitiative.org/sectors). On each company page, its emissions intensity path will be plotted on the same chart as the benchmark pathways for the relevant sector. Different companies can also be compared on the tool's main page, with the user free to choose which companies to include in the comparison.

3. Carbon Performance assessment of automobile manufacturers

3.1. Measuring companies' emissions intensities

The TPI Centre measures the emissions intensity of the auto manufacturing sector according to the average tank-to-wheel CO_2 emissions per kilometre of newly registered passenger cars globally, measured in terms of the WLTP. For individual manufacturers, the average is calculated at the fleet level. Sectoral benchmarks represent the average across all manufacturers' fleets.

The scope of this analysis is limited to passenger cars. Vehicle manufacturers are subject to different regulatory regimes covering vehicle performance in different jurisdictions. [15] In each one, a designated driving cycle is used to test vehicle emissions. The TPI Centre uses the WLTP, the 2021 test standard applied by the EU, as it directly measures CO_2 emissions per kilometre.[5] Other major regions use test cycles that report fuel efficiency instead (e.g. the Corporate Average Fuel Economy [CAFE] standard, which preceded the WLTC, is still used in the US and China, and the JC08 cycle is used in Japan).

In addition to passenger cars, data are sometimes published on smaller commercial vehicles, such as pickups, vans and minibuses, which are included in the classification of LDVs. As mentioned in the previous section, the TPI Centre focuses on passenger cars, as data are available for a wider range of countries than for the broader category of LDVs. However, there are slight variations in vehicle classifications between regulatory regimes. In the EU, the passenger car classification (category M1) covers vehicles "designed [...] for the carriage of passengers and not exceeding eight seats".[6] In contrast, under the CAFE standards in the US and China, classification is primarily made by weight, meaning that sports utility vehicles (SUVs) are classified as light trucks.[7] These variations are accepted because data are not available to adjust for the small discrepancies that result.

3.2. Calculating company emissions intensities

The TPI Centre estimates companies' future fleet emissions intensity on the basis of their published targets to reduce new vehicle emissions or improve new vehicle fuel efficiency. However, there are variations in the way in which companies specify targets, which require certain assumptions to be applied to estimate targets. For example:

- If targets are set relative to a base year before 2013, we estimate base year emissions by 'backcasting' from our most recently available company figure, using the recorded change in the company's vehicle emissions for that period.

[5] Since 1 September 2017, vehicle testing and type approval of vehicles in the EU has applied the World Harmonised Light Vehicle Test Procedure (WLTP). The TPI Centre's methodology reflects this update from previous NEDC test cycle as the new WLTP test cycle is suggested to better reflect real-world emissions.

[6] European Union Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009, Article 2 (Scope): http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009R0443

[7] EPA Emission Standards for LDVs, Trucks and Motorcycles: https://www.epa.gov/emission-standards-reference-guide/epa-emission-standards-light-duty-vehicles-and-trucks

- If targets are published for classes of vehicle that are broader than just passenger cars, we assume that targets apply equally to all vehicle sub-classes.
- If targets are published for well-to-wheel rather than tank-to-wheel emissions, we assume that targets apply proportionally to tank-to-wheel emissions.

It should be noted that the length of companies' emissions intensity pathways will vary depending on how much information companies provide on their recent emissions, and the time horizon for their emissions targets.

3.3. Estimating automobile manufacturers' historical and current emissions intensities

3.3.1. Overview

To estimate the current global average emissions intensity of manufacturers' new passenger car fleets, the TPI Centre combines regulatory data on emissions test results in different jurisdictions with individual companies' regional sales figures. Emissions or fuel economy data for new car registrations are published by regulators in the EU, US and China.[8] The data are often published by companies too, in their annual reports, sustainability reports or CDP disclosures, which in some cases include coverage of other jurisdictions. Sales data are also published by companies in annual reports, sales reports or closures.

3.3.2. Test cycle standardisation

Regulatory agencies in the US and China regulate and report fuel efficiencies rather than emissions intensities, and US regulators do so according to a test cycle different from the WLTP. US and Chinese data must therefore be harmonised into gCO_2/km, as measured by the WLTP. This is done using a methodology published by the ICCT, which involves regression analysis of data on test cycle results. The ICCT's report normalises fuel economy and efficiency data across test cycles based on an analysis of New Zealand's imported LDVs. This analysis establishes relationships that can be used to convert regional test cycle data from the EU, US, China and Japan to a CO_2-equivalent basis aligned with the WLTP.

Conversion from different test cycles to the WLTP involves the following steps: (i) unit conversion [11] (for the US, China, and Japan only); (ii) test cycle conversion; [7] (iii) weighting of fuel efficiency conversions according to the proportion of sales that are diesel versus petrol [gasoline].

(i) Unit conversion for the United States, China and Japan

The fuel type coefficient conversion method of the ICCT [11] is used to harmonise test cycles' units across regions in gCO_2/km separately for petrol and diesel cars. However, regulatory data aggregates values for both petrol and diesel cars. In the US, China and Japan, where diesel sales are negligible (1%, 1% and 4% respectively),[9] we assume that all cars sold are petrol cars. Hence, we adopt the unit and test cycle conversion relationship for petrol cars, unless specified otherwise.

For US fuel efficiency data, published in miles per gallon (mpg) according to the CAFE test cycle, we apply the following formula:

$$Y = Fuel\ type\ coefficient/X \qquad \textit{(Equation 1)}$$

In this formula, 'y' is emissions per kilometre (gCO_2/km, WLTP), 'x' is fuel efficiency in mpg according to CAFE, and the fuel type coefficient for petrol is 5,497. Some Japanese auto companies publish fuel efficiency data, and these must also be converted using the above formula. Japanese regulation covers fuel efficiency in kilometres per litre (km/L) according to the JC08 test cycle. The fuel type coefficient for petrol is 2,337.

[8] For the EU, this is the EU Environment Agency. In China, data are published by the Ministry of Industry and Information Technology (MIIT) and reproduced in English language reports by the Innovation Center for Energy and Transportation (iCET). For the US, data are published by the National Highway Traffic Safety Administration (NHTSA).

[9] Source: ICCT

Chinese fuel efficiency results are published in litres per 100 km (L/100 km) according to the WLTP test cycle from 2021 onwards and NEDC test cycle up to and including 2020. We apply the following formula, noting the Chinese fuel efficiency data are the inverse of the US and Japanese data:

$$Y = Fuel\ type\ coefficient * X \qquad \textit{(Equation 2)}$$

The fuel type coefficient for petrol is 23.4.

In cases where a company primarily sells diesel cars, we use conversion factors and relationships for diesel cars, assuming 100% diesel car sales. Detailed conversion factors and relationships can be found in the Appendix.

(ii) Test cycle conversion for the United States, China and Japan

Test cycle conversions are based on a methodology from ICCT. [7] This methodology describes the relationship between different test cycles and 3P-WLTP, the 3-Phase Worldwide Harmonised Light Vehicle Test Procedures currently used for certification in Japan. This is because ICCT analysis was conducted on vehicle sales in New Zealand, where the majority of passenger car imports come from Japan. [7] Europe uses the 4P-WLTP cycle, so we first convert all 3P-WLTP figures into 4P-WLTP, which is the test cycle adopted by the TPI Centre to harmonise emissions intensities across company assessments.

For the US, China and Japan, we adopt the following relationship, assuming 100% petrol cars:

$$4PWLTP = \frac{[\alpha(from\ cycle)+\beta]+31.0519}{1.1569} \qquad \textit{(Equation 3)}$$

For the US, conversion from CAFE to 4P-WLTP is required for all historical years. For China, conversion from NEDC to 4P-WLTP is required for data up to and including 2020. For Japan, conversion from JC08 to 4P-WLTP is required for all historical years.

Table 2. Conversion factors used for test cycle conversions

Conversion from	Fuel type	α	β
NEDC	Petrol	1.1194	-1.1618
JC08		0.9695	24.6742
CAFE		1.2094	-16.4856

(iii) Test cycle conversion for the European Union

A different test cycle conversion is used for the EU due to the continued importance of diesel cars there, although their purchase is decreasing: according to the ICCT, the diesel car market share in the EU fell from 55% in 2011 to 29% in 2020. [12]

During the initial adoption of the WLTP test cycle, the EU regulators required the publication of both NEDC and WLTP values for most manufacturers in 2019 and 2020. To convert historical intensities, we calculated the company-specific average WLTP/NEDC ratio across 2019 and 2020. We then applied this ratio to the emissions intensities reported only in NEDC prior to 2019.

3.3.3. Using regional data to calculate a global average for companies

The availability of EU, US and Chinese emissions data is a good starting point for calculating manufacturers' global-average fleet emissions intensity, as these three markets make up about two-thirds of the global market for new cars.[10] However, most companies sell cars outside of these markets, where emissions data are generally unavailable.

Companies often disclose sales data that cover a number of countries and regions, typically reflecting where their sales are concentrated. For almost all companies, verified sales data are available for some markets outside the EU, US and China. For other markets, the TPI Centre estimates average fleet emissions intensity using ratios of how regional emissions intensities relate to the US and EU over the period 20a–2021 (see Table 3 below).[11, 12]

Table 3. Regional passenger car average CO_2 emissions per km relative to the EU and US.

		Africa	Australia	Latin America	Canada	China	EU-28	India	Japan	Mexico	Middle East	Other Europe	Eurasia	South Korea	Other Asia-	US
Relative to EU-28	2013	1.149	1.302	1.239	1.209	1.198	1.000	0.777	1.014	1.250	1.405	1.046	1.369	1.074	1.149	1.368
	2014	1.167	1.304	1.258	1.209	1.190	1.000	0.778	1.026	1.241	1.427	1.062	1.390	1.074	1.167	1.351
	2015	1.185	1.306	1.278	1.208	1.181	1.000	0.778	1.037	1.231	1.449	1.079	1.412	1.074	1.185	1.333
	2016	1.234	1.360	1.299	1.223	1.162	1.000	0.789	1.042	1.271	1.466	1.092	1.429	1.051	1.200	1.344
	2017	1.288	1.419	1.322	1.238	1.142	1.000	0.801	1.048	1.314	1.484	1.106	1.448	1.026	1.215	1.356
	2018	1.346	1.483	1.347	1.256	1.120	1.000	0.814	1.055	1.361	1.504	1.121	1.468	0.999	1.232	1.369
	2019	1.410	1.553	1.374	1.274	1.096	1.000	0.828	1.062	1.412	1.525	1.138	1.490	0.969	1.251	1.383
	2020	1.480	1.630	1.405	1.295	1.069	1.000	0.844	1.069	1.468	1.549	1.156	1.514	0.936	1.272	1.399
	2021	1.460	1.609	1.385	1.277	1.055	1.000	0.832	1.055	1.448	1.528	1.140	1.494	0.923	1.255	1.380
Relative to US	2013	0.840	0.951	0.906	0.884	0.876	0.731	0.568	0.741	0.913	1.027	0.764	1.001	0.785	0.840	1.000
	2014	0.864	0.965	0.931	0.895	0.881	0.740	0.576	0.759	0.918	1.056	0.786	1.029	0.795	0.864	1.000
	2015	0.889	0.979	0.958	0.906	0.885	0.750	0.583	0.778	0.924	1.087	0.809	1.059	0.806	0.889	1.000
	2016	0.918	1.011	0.966	0.910	0.864	0.744	0.587	0.775	0.945	1.090	0.812	1.063	0.782	0.892	1.000
	2017	0.950	1.046	0.975	0.913	0.842	0.737	0.591	0.773	0.969	1.094	0.815	1.068	0.757	0.896	1.000
	2018	0.983	1.083	0.984	0.917	0.818	0.730	0.594	0.770	0.994	1.098	0.819	1.072	0.730	0.900	1.000
	2019	1.019	1.123	0.994	0.921	0.792	0.723	0.599	0.768	1.021	1.103	0.822	1.077	0.701	0.904	1.000
	2020	1.058	1.165	1.004	0.926	0.764	0.715	0.603	0.764	1.050	1.107	0.826	1.083	0.669	0.909	1.000
	2021	1.058	1.166	1.005	0.925	0.764	0.725	0.603	0.764	1.050	1.107	0.826	1.083	0.669	0.909	1.000

Still, very few companies provide a comprehensive breakdown of regional sales, meaning that some portion of sales remains unallocated to any particular market. When this is the case, we assume that the average emissions intensity that we are able to calculate for countries and regions where sales data are available is representative of the manufacturers' global sales. This is unlikely to be problematic as companies usually report the location of more than 85% of their sales.

3.4. Worked example

3.4.1. Historical emissions intensity

'Company A' publishes tailpipe new vehicle emissions data covering vehicles sold in the EU in gCO_2/km according to the NEDC and WLTP for 2019–2020 and the WLTP for 2021 (see Table 4 below). The company reports fuel efficiency data for new vehicles sold in the US (mpg, CAFE), and China (L/100km, NEDC for 2019–2020 and WLTP for 2021). These data can be used alongside a sales breakdown to calculate Company A's new vehicle average emissions intensity between 2019 and 2021.

[10] Based on calendar year 2016 data (EFTA sales included with EU), International Organization of Motor Vehicle Manufacturers (OICA): https://www.oica.net/category/sales-statistics/

[11] Source: ICCT data on annual well-to-wheel CO_2/km for 2013–2020.

[12] Where sales data are available for countries that have very similar fleet emissions intensity to the EU, US or China, these data are apportioned to the EU, US or China respectively. In particular, any sales in NAFTA (North America Free Trade Agreement) countries (Canada, Mexico and US) are attributed to the US. When no distinction was made between sales in China and in 'other Asia-Pacific', sales were assumed to refer to China only, hence Chinese emissions were assumed to apply. All countries that might be reported as being within the continent of Europe are apportioned to the EU, apart from Russia, whose average emissions intensity is closer to the US.

Table 4. Company A emissions intensity data for new vehicles sold in the EU, and fuel efficiency data for new vehicles sold in US and China

Region	Disclosed variable	2019	2020	2021
EU	gCO_2/km, WLTP	140.43	120.12	106.87
EU	gCO_2/km, NEDC	122.35	103.70	N/A
US	mpg, CAFE	37.70	37.80	39.10
China	L/100km, NEDC for 2019-2020; WLTP for 2021	5.92	5.85	5.93

Note: These numbers are rounded for ease of presentation.

US, Chinese and Japanese fuel efficiencies are converted to emissions intensities in gCO_2/km using the ratio for petrol cars.

$$Y_{US\ emissions\ intensity\ (gCO2/km, CAFÉ)} = \frac{5{,}497}{X} \quad \textit{(Equation 4)}$$

$$Y_{\text{Chinese emissions intensity }(gCO_2\text{/km,WLTP for 2021,NEDC for 2019–2020})} = \frac{5{,}497}{X} \quad \textit{(Equation 5)}$$

Emissions intensities in a common unit (gCO_2/km) but still according to different test cycles are then converted into the harmonised WLTP.

$$US, WLTP_{\text{gCO}_2\text{/km}} = \frac{[1.2094*Y-16.4856]+31.0519}{1.1569} \quad \textit{(Equation 6)}$$

$$China, WLTP_{\text{gCO}_2\text{/km (2019–2020)}} = \frac{[1.1194*Y-1.1618]+31.0519}{1.1569} \quad \textit{(Equation 7)}$$

The EU data do not need unit conversion, but the NEDC emissions intensities must be converted into WLTP emissions intensities. The average WLTP/NEDC ratio of 2019 and 2020 is:

$$\left[\left(\frac{WLTP}{NEDC}\right)_{2019} + \left(\frac{WLTP}{NEDC}\right)_{2020}\right]/2 = \left[\left(\frac{120.12}{103.70}\right) + \left(\frac{140.43}{122.35}\right)\right]/2 = 1.15 \quad \textit{(Equation 8)}$$

We apply this ratio to all historical figures prior to 2019. For example, the NEDC value for 2018 is 121.09. The WLTP value for 2018 is therefore 139.62 (121.09 × 1.15). These conversions result in the average regional emissions intensities for the period from 2019 to 2021 shown in Table 5.

Table 5. Average regional emissions intensities (WLTP), 2019 to 2021

Region	Emissions intensity	2019	2020	2021
EU	gCO_2/km, WLTP	140.43	120.12	106.87
US	gCO_2/km, WLTP	165.02	164.62	159.57
China	gCO_2/km, WLTP	159.69	158.11	138.58

These intensities are then weighted by the company's regional sales data to provide global averages. The company's sales data is shown in Table 6 below.

Table 6. Company A's sales data (thousands) by region, 2019 to 2021

	2019	2020	2021
EU	753	651	759
NAFTA (Canada, Mexico and the US)	692	659	781
China	259	224	154
India	45	140	183
South Korea	520	N/A	N/A
Other Asia	134	120	153
LATAM	231	156	192
Africa	64	42	59
Middle East	134	120	146

It is assumed that NAFTA emissions are the same as the US. For companies selling in markets not covered by published emissions data, the corresponding regional emissions intensity is estimated from ICCT's well-to-wheel historical country new vehicle average gCO_2/km emissions (see Table 3 above). The coefficient used would be the ratio relative to the largest sales market for the assessed company. The resulting regional emissions intensities are shown in Table 7 below.

Table 7. Regional emissions intensities, 2019 to 2021 (gCO_2/km)

	2019	2020	2021
India	98.80	99.32	96.23
South Korea	115.62	110.20	106.71
Other Asia	149.26	149.65	145.06
LATAM	163.97	165.30	160.14
Africa	175.07	178.22	172.71
Middle East	181.97	182.31	176.66

After applying sales weightings across all regional emissions intensities (gCO_2/km, WLTP), Company A's global average emissions intensity can be calculated (see Table 8 below).

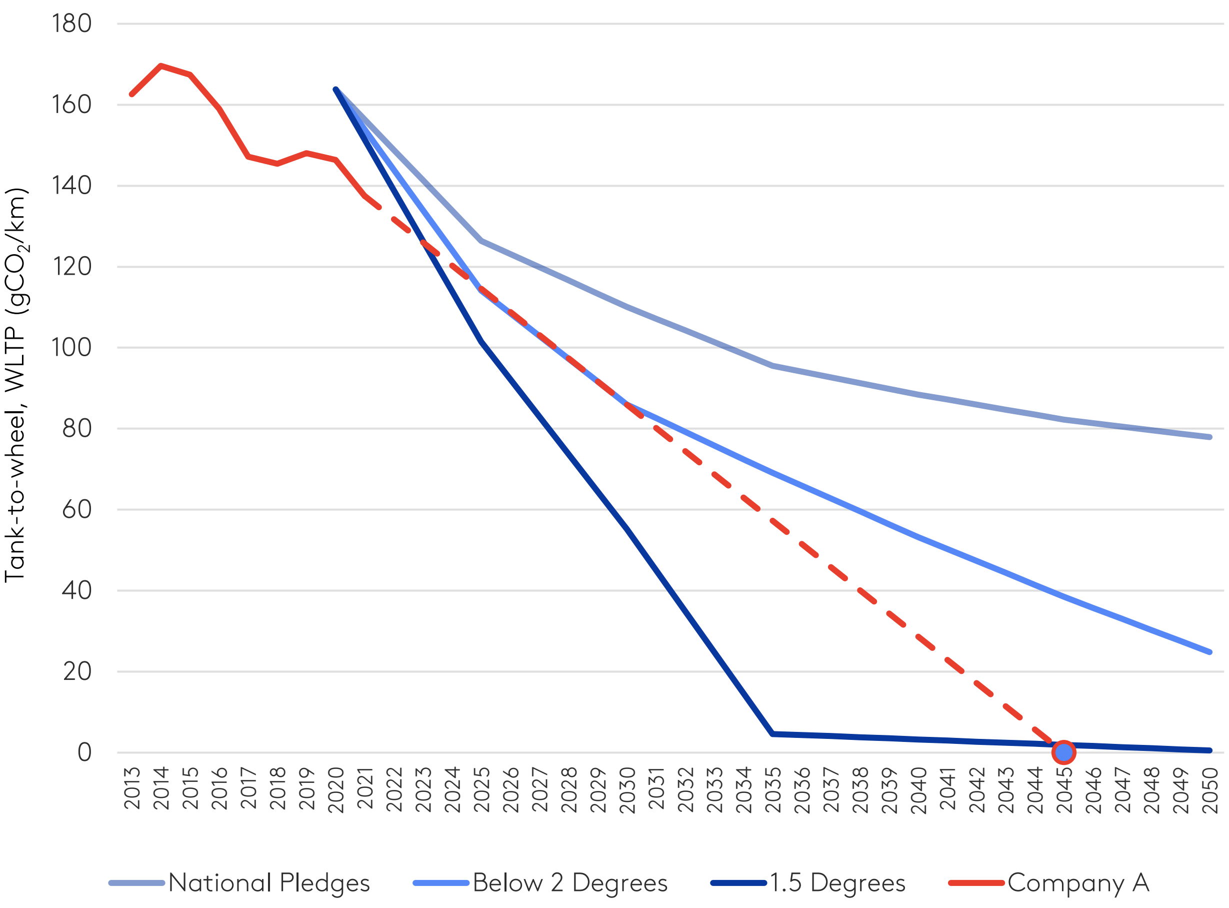
Table 8. Company A new passenger vehicle registrations, 2019 to 2021 (gCO_2/km)

	2019	2020	2021
Average gCO_2/km, WLTP	148.07	146.34	137.46

3.4.2. Future emissions intensity and final pathway

Company A commits to 100% global electrification by 2045. We interpret this as achieving net zero emissions in the use-phase for all new vehicles in 2045, hence, the company's 2045 emissions intensity is 0 gCO_2/km.

Figure 2. Company A's Carbon Performance pathway



4. Discussion

The TPI Centre's approach to assessing the Carbon Performance of the auto manufacturing sector aims to be easy to understand and use while also being robust. However, there are unavoidable uncertainties and judgements made in the development of the methodology, as well as in individual company assessments. Investors may wish to dig deeper into companies' assessments in their engagements with them to better understand these.

4.1. General issues

The methodology builds on the Sectoral Decarbonisation Approach (SDA), which compares a company's emissions intensity with sector-specific benchmarks that are consistent with international targets (i.e. limiting global warming to 1.5°C, well below 2°C, and the sum of National Pledges).

The TPI Centre uses IEA modelling to calculate the benchmark pathways. The IEA modelling has several advantages, but it is also subject to limitations, like all other economy–energy modelling. Model projections often turn out to be wrong. This could impact the accuracy of the benchmark and potentially lead to investors drawing inaccurate conclusions about a company's alignment. The IEA frequently updates its modelling, and the TPI Centre plans to update its benchmark calculations accordingly. However, in such a forward-looking exercise there is no way to avoid the uncertainty created by projecting into the future.

The TPI Centre predominantly uses disclosed emissions and activity data to derive emissions intensity pathways. While much of this data is audited, the emissions intensity estimates can only be as accurate as the underlying disclosures.

Estimating the recent, current and especially the future emissions intensity of companies involves making several assumptions. It is therefore important to bear in mind that in some cases the emissions pathway drawn up for each company by the TPI Centre is an estimate based on information disclosed by companies, rather than the companies' own estimate or target. In other cases, the information disclosed by companies is sufficient on its own to completely characterise the emissions intensity pathway.

4.2. Issues specific to the automobile manufacturing sector

The Carbon Performance assessment for the auto manufacturing sector requires a distinct approach to applying the SDA compared with other sectors that the TPI Centre has covered to date, including electricity, cement and steel. The key difference is that our assessment focuses on the emissions performance of auto manufacturers' new vehicles, rather than the emissions intensity of the manufacturing process itself. This is justified on the grounds that it is downstream of manufacturing where auto manufacturers' lifecycle carbon emissions are concentrated.

To derive company pathways for new vehicle emissions, regulatory data on emissions performance or fuel efficiency are combined with company sales data. The main challenges encountered here include converting regulatory emissions data to a common basis, which involves some uncertainties but still rests on strong empirical data. Additionally, emissions performance data for countries and regions outside of the EU, US and China are obtained by assuming that variations at the company level mirror variations at the sector level.

As with other sectors, this analysis is highly dependent on companies' disclosures. In the auto manufacturing sector, this poses three particular challenges:

- First, passenger cars are defined differently by the different regional regulatory bodies to whom companies report their emissions intensities, and also by the companies themselves. For instance, Chinese and US industry bodies classify some SUVs, minivans and pickups as 'light trucks' rather than regular passenger cars. Meanwhile, companies may classify these vehicles as 'passenger cars' in their disclosed sales volumes. Consequently, in some regions there can be a discrepancy between the company's car sample used to calculate the company's average emissions intensity (excluding light trucks) and the sample of cars used for the regional sales weighting (including some light trucks). This can result in an underestimate of a company's overall intensity, especially for auto manufacturers that sell a larger number of big passenger cars such as SUVs and pickups in the US.

- Second, there have been controversies around auto manufacturers' efforts to minimise their intensities in official emissions tests. Research by the ICCT has shown that there is an increasing divergence between the emissions intensities of official tests and real-world emissions, leading to an underestimation in the latter. [13] This problem is partially addressed by the TPI Centre's shift towards adopting the WLTP in our assessments. The new WLTP cycle is believed to better reflect real-world performance by reducing the discrepancy with real-world emissions to approximately 14% (from the 40% suggested by a previous NEDC test cycle).
- Third, the TPI Centre acknowledges that the introduction of zero tailpipe emission vehicles in low-carbon scenarios increases the significance of operational and upstream emissions in the auto manufacturing value chain. As the large majority of new passenger car sales are still ICE vehicles [14], the bulk of value chain emissions from new car sales still occurs in the use phase. The very limited availability of modelling and company disclosures that report Scope 1 and 2 emissions, as well as Scope 3 upstream emissions for new passenger vehicle sales, also poses a challenge. Currently, EVs are treated as having zero emissions. This is consistent with how regulators around the world have decided to treat EVs and how they are accounted for in the benchmark scenarios. However, if countries' electricity grids are not delivering electricity generated with zero emissions, charging EVs cannot be carbon-free.

These three limitations are currently accepted in the methodology as they cannot be solved with more accurate and comprehensive data. For these reasons, we conclude that our estimates should be considered as a lower-bound estimate for most companies.

Disclaimer

1. Data and information published in this report and on the TPI Centre website are intended principally for investor use but, before any such use, you should read the TPI Centre's website terms and conditions to ensure you are complying with some basic requirements which are designed to safeguard the TPI Centre whilst allowing sensible and open use of TPI data. References in these terms and conditions to "data" or "information" on the website shall include the Carbon Performance data, the Management Quality indicators or scores, and all related information.
2. By accessing the data and information published in this report and on the website, you acknowledge that you understand and agree to the website terms and conditions. In particular, please read paragraphs 4 and 5 below which detail certain data use restrictions.
3. The data and information provided by the TPI Centre can be used by you in a variety of ways – such as to inform your investment research, your corporate engagement and proxy-voting, to analyse your portfolios and publish the outcomes to demonstrate to your stakeholders your delivery of climate policy objectives and to support TPI Centre in its mission. However, you must make your own decisions on how to use TPI data. The TPI Centre cannot guarantee the accuracy of any data made available, the data and information on the website is not intended to constitute or form the basis of any advice (investment, professional or otherwise), and the TPI Centre does not accept any liability for any claim or loss arising from any use of, or reliance on, the data or information. Furthermore, the TPI Centre does not impose any obligations on supporting organisations to use TPI Centre's data in any particular way. It is for individual organisations to determine the most appropriate ways in which the TPI Centre's data can be helpful to their internal processes.
4. Subject to paragraph 3 above, the Management Quality and the Carbon Performance indicators that are part of the TPI online tool and available publicly on the TPI Centre's website are:
   - Free, if they are used for internal and not commercial purposes, including for research, as one of the inputs to inform portfolio construction, for financial decision-making including cases of lending and underwriting, for engagement and client reporting, for use in proprietary models as part of climate transition analysis and active investment management.
   - Restricted, unless licensed where the use is for further commercial exploitation through redistribution, derived data creation, analytics, and index or fund creation (inclusive of where the index is used as the basis for the creation of a financial product, or where TPI data is a key constituent of a fund's construction).
5. Notwithstanding any other provision of these website terms and conditions, none of the data or information on the website may be reproduced or made available by you to any other person except that you may reproduce an insubstantial amount of the data or information on the website for the uses permitted above.
6. The data and information on the website may not be used in any way other than as permitted above. If you would like to use any such data or information in a manner that is not permitted above, you will need the TPI Centre's written permission. In this regard, please email all inquiries to info@transitionpathwayinitiative.org.

References

[1] Randers J (2012) Greenhouse gas emissions per unit of value added ('GEVA'): a corporate guide to voluntary climate action. *Energy Policy* 48: 46–55.

[2] International Energy Agency [IEA] (2022) *World Energy Outlook 2022*. https://www.iea.org/reports/world-energy-outlook-2022

[3] IEA (2021) Mobility Model (MoMo) Model. https://www.iea.org/data-and-statistics/charts/trajectories-of-rated-fuel-economy-of-new-light-duty-vehicles-against-global-fuel-economy-initiative-targets-and-iea-scenarios-2005-2050

[4] IEA (2021) *Net Zero by 2050 - A Roadmap for the Global Energy Sector*. https://www.iea.org/reports/net-zero-by-2050

[5] IEA (2023) *Global EV Outlook 2023*. https://www.iea.org/reports/global-ev-outlook-2023

[6] IEA (2021) *Global Fuel Economy Initiative 2021*. https://www.iea.org/reports/global-fuel-economy-initiative-2021

[7] International Council on Clean Transportation [ICCT] (2021) *Methods of converting the type-approval fuel economy and CO2 emission values of light vehicles: An analysis for New Zealand*. https://theicct.org/publication/methods-of-converting-the-type-approval-fuel-economy-and-co2-emission-values-of-light-vehicles-an-analysis-for-new-zealand/

[8] T. E. A. M. Association, "ACEA Driving Mobility for Europe," ACEA, 2023. https://www.acea.auto/figure/new-passenger-car-registrations-in-units/

[9] T. E. A. M. Association, "ACEA Driving Mobility for Europe," ACEA, 2023. https://www.acea.auto/figure/new-commercial-vehicle-registrations-in-units/

[10] ICCT (2012) *Global transportation energy and climate roadmap*. https://theicct.org/wp-content/uploads/2021/06/ICCT-Roadmap-Energy-Report.pdf

[11] ICCT (2014) *Development of test cycle conversion factors among worldwide light-duty vehicle CO_2 emission standards*. https://theicct.org/publication/development-of-test-cycle-conversion-factors-among-worldwide-light-duty-vehicle-co2-emission-standards/

[12] ICCT (2021) *European Vehicle Market Statistics 2021–2022*. https://theicct.org/publication/european-vehicle-market-statistics-2021-2022/

[13] ICCT (2020) *On the way to real world CO_2 values: The European passenger car market in its first year after introducing the WLTP*. https://theicct.org/publication/on-the-way-to-real-world-co2-values-the-european-passenger-car-market-in-its-first-year-after-introducing-the-wltp/

[14] IEA (n.d.) Electric vehicles. Web page. https://www.iea.org/reports/electric-vehicles

[15] Passenger vehicle greenhouse gas emissions and fuel consumption (2023) International Council on Clean Transportation. https://theicct.org/pv-fuel-economy/

Appendix: Conversion factors and relationship for diesel cars

Table A1. Unit conversion for diesel cars into gCO_2/km

Conversion from	Conversion to	Value
Mpg	gCO_2/km	6,315
Km/L	gCO_2/km	2,684
L/100km	gCO_2/km	26.8

Table A2. Unit conversion for diesel cars into gCO_2/km

From cycle	Fuel type	α	β
NEDC	Diesel	1.0871	12.7300
JC08		0.9695	27.4167
CAFE		1.1589	-16.5771

Equation 9 shows the test cycle conversion for diesel cars into gCO_2/km using values from Table A2.

$$4PWLTP = \frac{[\alpha(from\ cycle)+\beta]+31.0519}{1.1569} \qquad \text{(Equation 9)}$$

LSE Transition Pathway Initiative Centre

Grantham Research Institute on Climate Change and the Environment

London School of Economics and Political Science

Houghton Street

London WC2A 2AE, UK

T +44 (0)20 7107 5027

E tpi@lse.ac.uk

Transition Pathway Initiative

C/o UNPRI Association

5th Floor, 25 Camperdown Street

London E1 8DZ, UK

T +44 (0)20 3714 3141

E tpi@unpri.org

@tp_initiative

transitionpathwayinitiative.org

Transition Pathway Initiative

Grantham Research Institute on Climate Change and the Environment